The Haptic Hand

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ABSTRACT

The *haptic hand* is a greatly simplified robotic hand that is designed to mirror the human hand and provide haptic force feedback for applications in music. The "fingers" of the *haptic hand* device are laid out to align with four of the fingers of the human hand. A key is placed on each of the "fingers" so that a human hand can perform music by interacting with the keys. The *haptic hand* is distinguished from other haptic keyboards in the sense that each finger is meant to stay with a particular key. The *haptic hand* promotes unencumbered interaction with the keys. The user can easily position a finger over a key and press downward to activate it—the user does not need to insert his or her fingers into an unwieldy exoskeleton or set of thimbles.

An example video demonstrates some musical ideas afforded by this open-source software and hardware project.[1]

Author Keywords

NIME, haptic, haptic hand, open-source hardware, sound and music computing, motorized fader

ACM Classification

H.5.5 [Information Interfaces and Presentation] Sound and Music Computing, H.5.2 [Information Interfaces and Presentation] User Interfaces—Haptic I/O, I.2.9 [Artificial Intelligence] Robotics—Propelling mechanisms.

1. INTRODUCTION

Since as early 1978, music technology researchers have been investigating how to provide musical instruments with haptic force feedback [5]. For example, J.-L. Florens, A. Luciani, C. Cadoz, and N. Castagné have created a 16-key system [6]. Subsequent work has involved extending the system to more keys and laying them out according to the shape of a piano keyboard [3]. However, this technology is expensive enough that building and using 88-key force-feedback pianos would be challenging.

Therefore, it is worthwhile to think about incorporating this technology into useful musical systems with fewer keys. For example, in the present paper, the authors suggest considering alternative musical mappings so that only one key per active finger is required—in other words, the fingers remain with the certain keys instead of switching keys like on a piano.

2. RELATED WORK IN ROBOTICS

Further related work can be found in the field of robotics. A series of wearable and/or exoskeleton haptic devices have been created for delivering various magnitudes of force feedback to the fingers. One notable example is CyberGrasp,[2] which is a glove that delivers haptic force feedback to the fingers using a system of cables. Many other related robotic haptic devices are described in a review article [5].

The form and dynamics of the hand itself are inspiring. If one considers what the ultimate human-computer touch-based interface could be for interacting with the hands, it seems reasonable that it should be impedance matched to the human hands or at least be able to present a similar mechanical impedance. Consequently, a haptic device that models the human hands is of particular interest. HIRO III, which is a highly optimized five-fingered haptic interface robot, can move and present force feedback with dexterity [4]. The user touches each of his or her fingertips to the finger tips of the HIRO robot, which present the haptic force-feedback in 21 degrees-of-freedom (not shown).

3. THE HAPTIC HAND

It is informative to compare the shapes of human hands. Figure 1 shows the outlines of nine PhD students' hands overlaid on top of each other. The outlines of the index and middle fingers are aligned with each other, based on the assumption that the haptic hand would have keys for at least the index and middle fingers. By consulting Figure 1, one can observe that the ring fingers are also fairly well aligned, but the thumb and pinky fingers are not particularly well aligned.

Because furthermore the tip of the thumb tends to move in a different plane than the tips of the fingers, no key for the thumb is provided. This simplifies the mechanical design signficantly, enabling the cost to be decreased. The *haptic hand* device therefore provides keys for the index, middle, ring, and pinky fingers (see the dotted red key outlines in Figure 1. Although the "pinky key" may be more or less accessible to some musicians, a key is nonetheless provided for the pinky finger because it moves in the same plane as the other included fingers, and it is convenient to have an even number of motor channels total.

To keep costs low and to promote compatibility with other open-source software and hardware for music, the

[1] `https://github.com/eberdahl/Open-Source-Haptics-For-Artists/tree/master/Hardware/HapticHand`

[2] `http://www.cyberglovesystems.com`

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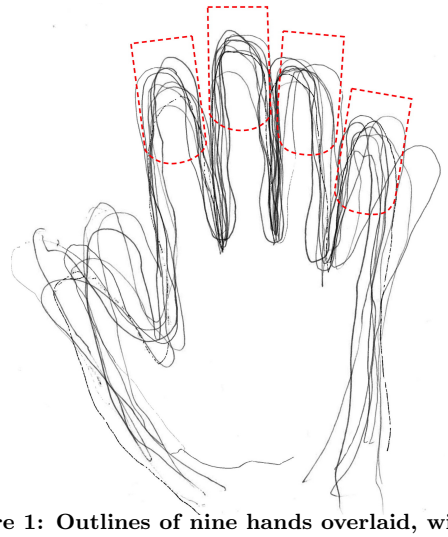

Figure 1: Outlines of nine hands overlaid, with the keys depicted in dashed red.

Figure 2: The haptic hand force-feedback device.

haptic hand hardware is derived from the open-source FireFader haptic device [2]. It has essentially been created by using two instances of the FireFader circuit, rotating the motorized faders so that they are oriented vertically, designing a surrounding enclosure to house the electronics, and attaching keys. It was decided to use ALPS faders with 60mm of travel instead of 100mm of travel to more closely match comfortable smaller motions of the human fingers.

The keys are touch sensitive so that the device can detect whether or not a key is being touched by the user. This is achieved by carefully attaching the keys to the motorized faders, painting the keys with a black conductive paint, and then putting a varnish on top of the conductive paint.

4. PROGRAMMING

Although the electronics and mechanical parts for the *haptic hand* are very similar to those of the FireFader, there are significant differences in the requirements for programming these two devices. While FireFader users typically grip the motorized fader knobs tightly, users' fingers tend to be less strongly coupled to the keys of the *haptic hand*. Consequently, many successful programs for the *haptic hand* will incorporate a virtual contact spring (also known as "BUT" [7]) or a similar restoring force to push the key upward into the human finger, allowing for continuous control.

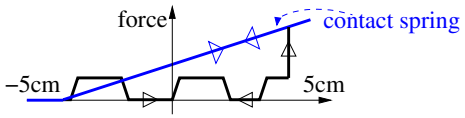

Figure 3: Switching between a force profile (in thick black) and a contact spring force (in blue).

4.1 Haptic Drum

One way to keep the keys in contact with the user's fingers is to implement a kind of haptic drum algorithm, which incorporates a contact spring [1]. In this case, each of the fingers can even be used to independently play one-fingered drum rolls: `https://www.cct.lsu.edu/~eberdahl/m/HD.mov`

4.2 Force Profile

An intriguing idea is to use a force profile to program the force feedback [8]. A user can draw into the force profile to customize the feel, which allows various haptic designs to be rapidly tested. However, not all force profiles will incorporate a returning force. Therefore, it was decided to switch between a force profile and a contact link. In this manner, the user explores the force profile while pressing downward, then when the user reaches the bottom of the stroke, the force feedback is calculated using a contact spring instead of the force profile. This continues until the user's finger rises above the threshold where the contact spring's force decreases to zero (see Figure 3). Then the mode of the force feedback switches back to the force profile so that the cycle can start again. In the following example, a sound is triggered, each time the user reaches the edge of a "hump" in the force profile: `https://www.cct.lsu.edu/~eberdahl/m/FP.mov`

In summary, despite the low-cost design of the *haptic hand*, it can be used successfully for implementing some intriguing multi-finger musical interactions.

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